ABSTRACT

In recent years, the business fraternity faces growing complexity due to its fast and rising competitive environment in the global arena. Their supply chain function becomes increasingly important and integrated worldwide. The performance of a supply chain design critically depends upon strategic warehousing decision. Warehouse design decisions could not be made alone as it affects the other supply chain drivers also. Today’s warehousing decision promotes a complete supply chain solution. Unfortunately, comprehensive literatures survey in this domain indicates lack of broad-viewed programmed structures in spite of having a huge strategic dimension attached to it. Most of the time conventional decision making approaches have the limitations to solve real life complex warehouse selection problems and frequently led to make confusing, over-simplified, computationally complex and time consuming rather than alleviating and solving problems. Moreover, difficulties in assessment of exact criteria weights, appropriate situational analysis, interpretation and conversion to numerical/fuzzy terms etc. led the decision makers towards inaccurate and imprecise decisions. Decision support frameworks (DSFs) synchronize and integrate the supply chain drivers, warehousing decision variables and the levels of decision hierarchy. Hence, DSF acts as a guide/road map in warehouse performance evaluation under supply chain perspectives and helps to build a benchmark strategy in improving customer satisfaction level thus sustain and augment its competitive advantages effectively.

In this context, the research work developed four novel decision support frameworks (DSFs) based on management science; economical approach and decision theory of operations research to evaluate warehouse’s performances in different decision environments. Four real life industrial case studies in different Eastern Indian companies revalidate those developed DSFs. The main contributions of the research work are the proposed multi objective performance analysis (MOPA) technique in DSF-I; three integrated fuzzy multiple criteria decision-making (FMCDM) approach based on subjective and objective criteria in DSF-II; a hybrid fuzzy technique based FMCDM model in DSF-III; and an MCGDM model based on group heterogeneity in DSF-IV. For validation, proven and popular MCDM tools SAW, MOORA, TOPSIS, VIKOR, ELECTRE(C), ELECTRE (D) and PROMETHEE are also utilized according
to the given environment and requirements. Here, development of each of these four DSFs is sequentially briefed in terms of their illustration, result analysis, validation and revalidation.

**DSF-I** introduced multi objective performance analysis (MOPA), a novel MCDM approach employing a unique modified weight concept to solve six decision problems in real life industrial scenario. This innovative modified weight concept is employed to modify the weights of the criteria in order to reduce the affect of the inherent inaccuracy involved with direct use of weights. Modified weight is directly proportional to the initial weight, remains positive and greater than the initial weight. Performances of the respective decision alternatives are compared with the cited work as well as other popular MCDM methods SAW, MOORA, TOPSIS, VIKOR, ELECTRE(C) and ELECTRE (D) for validation. During result analysis, analysis of variance (ANOVA) revealed that the modified weight concept reduced the relative dispersion of weights significantly (p < 0.5), lead to precisely accurate decision. The consistency of results of the same cited problems with those of other works is checked for statistical significance (p < 0.5) each time which strongly justified the concept of modification of weight. IBM SPSS version-20 based ANOVA results along with Tukey’s multiple comparisons statistically validated the significance of numerical outputs (p < 0.5) in different phases of problem solutions. Sensitivity analysis (SA) and other investigations also found MOPA as a simple, robust, effective and precise decision making tool. Analysis indicated the capability of MOPA to overcome rank reversal problem to a great extent. The investigation proved MOPA of the DSF-I, as a novel precisely accurate multi criteria decision making (MCDM) tool.

**DSF-II** comprises of three new extended fuzzy multi criteria decision making methodologies capable of handling subjective and objective factors for the evaluation and selection of warehouse location. The concept of fuzzy set theory is integrated with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weight (SAW) and Multi Objective Optimization on the basis of Ratio Analysis (MOORA) methods to assess subjective criteria in terms of subjective factor measures. A classical normalization technique is employed to assess the objective criteria in terms of objective factor measures. Subjective factor measures and objective factor measures are integrated by Brown and Gibson model to calculate warehouse
location selection index. The proposed methods are illustrated with two examples of warehouse location selection. Comparative study of the results show that the integrated FMCDM techniques based on subjective and objective criteria are simple and accurate decision making process. Moreover, sensitivity analysis shows that the proposed methods have the capability to trade-off between the subjective and objective judgments while choosing competing location alternatives. The proposed methodologies also have the potential to effectively deal with such decision problems without the prerequisite information of the objective criteria weights. Sensitivity analysis reveals the robustness of the proposed methodologies under diverse decision making attitudes. To confirm the simplicity of the proposed algorithms over FAHP, it is found that computational running times of the proposed methodologies are lesser than FAHP method. The proposed methodologies of the DSF-II could be treated as effective decision making aid to the supply chain managers.

In DSF-III, a novel hybrid fuzzy multi criteria decision making (FMCDM) technique based on SAW and FRS techniques is proposed to make warehousing decision. Pair wise assessment of the preference relationships between the alternatives generate fuzzy preference relation matrix (FPRM). Introduction of row sum and column sum operations on FPRM and its illustration with a benchmark distribution center selection problem established the proposed methodology as one of the most erudite decision making tool in a supply chain.

DSF-IV advocated group decision making (GDM) in extracting the real case scenarios of the decision problems efficiently to add competitive advantages in a supply chain. Group members from wider spectrum of the environment naturally command variation in knowledge level to their respective domain. The degree of heterogeneity of the decision makers in a group plays a crucial role in realistic assessment of both alternatives and selection criteria. The proposed new Multi criteria GDM approach in adroit exploitation of the group heterogeneity during evaluation process could restrict the biasness of available information while decision making. The importance of the heterogeneous degree of expertise is established through pair wise preference comparison matrix. To reduce the biasness to a larger extent, the consistency check mechanism of analytical hierarchy process (AHP) is employed. The proposed algorithm is illustrated with a real life case example to an Indian automobile company to select an
appropriate warehouse location for its new plant. In order to demonstrate the compatibility of the proposed algorithm, seven different MCDM methods SAW, MOORA, TOPSIS, VIKOR, ELECTRE II, COPRAS and PROMETHEE are also applied on the same case problem. The new approach followed a rigorous incremental sensitivity analysis considering both hetero/homogeneous environments. Analysis indicated that the degree of expertise of the decision makers have decisive impact towards final decisions and found the proposed group decision making approach as a robust decision making aid. Group heterogeneity concept in the new algorithm is truly capable of realistic decision making in a complex supply chain. The new approach found to be highly effective MCGDM tool for the supply chain managers in a firm.

All the four DSFs are also revalidated through implementing them directly to some real case studies of warehouse performance evaluation in different eastern Indian companies. Developing decision support framework is a continuous process. It is paramount to assess the selection made as it is done during performance evaluation of the warehouses in different industries. Even the pitfalls of this selection phase are considered as a valuable input in modifying the next selection process. Thus a decision support framework is aimed at simplifying the overall decision making process and increases its effectiveness itself. This optimized warehouse decision design would effectively support the competitive strategy of the organization.

The pragmatic findings and impact of the DSFs relating to the overall research questions are discussed. Subsequently the implications and contributions of the research findings are also revalidated as the best practice observed from the case studies. It is concluded that the viewpoint of the decision support frameworks (DSFs) of warehouse performance evaluation is very much compatible with present day’s industrial requirements and the merits of the proposed techniques can outperform the similar approaches by providing fabulous results. This research work could also be treated as a continuous effort to provide an option (meeting Ashby’s Law) to the supply chain managers for better decision making to survive and prosper under highly competitive global business scenario.